1877, we find approximate places for 1875, of 134 out of 138 planets—materials for calculation not being available in four cases—and accurate opposition-ephemerides are given where the elements have been perturbed to the year, and for those planets for which Tables have been prepared. The initiated in these matters will be aware that a work of this extent involves a vast amount of labour, which will be greatly increased with the present rate of discoveries of new members of the group of small planets.

In some few instances the perturbations have been determined with every possible precision, with a particular object in view, as in the case of Themis, the motion of which was rigorously investigated by Dr. Krüger, for a determination of the mass of Jupiter; and for those planets whose perturbations have been thrown into the form of Tables, it was also necessary to settle the elements with great accuracy, though the results have not been in every case so satisfactory as might have been expected. We have now Tables of Amphitrite, by Becker; of Iris, Flora, and Victoria, by Brünnow; Egeria, by Hansen; Metis, Lutetia, and Pomona, by Lesser; and of Parthenope, Eunomia, Melpomene, and Harmonia, by Schubert.

Even with approximate places of these bodies, so long as they are situated within about 3° from the ecliptic, the charts of small stars now in the hands of astronomers allow of their being identified without much difficulty with the equatorial, and the errors of the predicted places being determined by this instrument, their meridional observation is greatly facilitated. Still, rough ephemerides must be prepared, and a considerable amount of time will be involved in ascertaining their errors, and as observations made with this purpose in view may be so conducted as to give positions pretty nearly as reliable as those generally resulting from meridional observations, we shall not be surprised to learn that the latter are soon relinquished, except perhaps for the older minor planets and for such as attain the brightness of stars of the eighth or ninth magnitude, and are accurately predicted. The subdivision of labour as regards observations does not appear to have so far worked very efficiently, though proposed many years since—another effort, however, may be necessary in this direction, and it may at least be expected that those who by their discoveries are so rapidly increasing the list of planets, will keep them in view for a sufficient length of time to allow of their elements being well determined.

Egeria, which has now about the brightness of an average star of the ninth magnitude, is favourably situated for observation; it has lately passed amongst the outliers of the Pleiades. The following places are for Berlin midnight:—

	R.A.	N.P.D.	Distance from earth.
	h. m. s.	° ′	
Nov. 18	3 18 59	65 53·3	1·478
,, 20	3 16 32	65 47·8	1·479
,, 22	3 14 6	65 42·6	1·481
,, 24	3 11 42	65 37·7	1·484
,, 26	3 9 21	65 33·1	1·488
,, 28	3 7 3	65 28·8	1·493

Lutetia, a bright eleventh magnitude, is approaching opposition. Places, also for Berlin midnight, are:—

	R.A.	N.P.D.	Distance from earth.
	h. m. s.	° ′	
Nov. 18	4 54 11	68 34·1	1·480
,, 20	4 52 8	68 35·0	1·477
,, 22	4 50 1	68 36·1	1·474
,, 24	4 47 52	68 37·3	1·472
,, 26	4 45 40	68 38·6	1·472
,, 28	4 43 26	68 40·0	1·472

SCIENCE TEACHING TO YOUNG CHILDREN

THE leading article in NATURE of Oct. 28, on the Sixth Report of the Science Commission has made me think that possibly a short account of an attempt to teach science to boys younger than those to whom that report refers, may be not without interest for some of your readers.

There are at present about fifty boys in this school, varying in age from seven to fourteen, the majority of whom are going to one or other of the great public schools. In order to attain the high standard of classical work necessary, half the school-hours have to be given up to Latin and Greek. Enough time still remains, however, even after providing for the requirements of mathematics, French, and the usual English subjects, to enable every boy to learn either botany or chemistry. For this purpose the school is divided into three classes, the lowest of which contains about twenty boys, whose average age is nine. Class II. is composed of ten boys of an average age of twelve, while the first class contains twelve boys of an average age of twelve and a half. Class III. has two lessons in botany of three-quarters of an hour each, and one hour's lesson on physical geography in the course of the week. The boys in it are taught to distinguish the parts of a flower, and by the help of a chart similar to that given by Mrs. Kitchener in her "Year's Botany" to discover the order to which any plant belongs. The winter is employed in learning the chart, and in studying the characters of the different orders as shown on Henslow's Botanical Diagrams. Illustrations taken from Sir John Lubbock's and Mr. Darwin's books, of the relations between plants and insects, and facts bearing on the geographical distribution and economical uses of plants, add interest to these lessons. The second class also does botany, but is able to give two-and-a-half hours per week to it. The standard of knowledge aimed at is such as is contained in Prof. Oliver's or Mrs. Kitchener's books and the boys are expected to be able to find out any given plant in Bentham's British Flora. The boys in Class I. learn chemistry, and spend one afternoon of one-and-a-half hours at practical work in a small laboratory. Another afternoon is employed in listening to a lecture founded upon Miller's Chemistry (Text-books of Science series). Two additional half-hours are given to getting up the portion of Miller lectured on, so as to be able to answer questions on it at the beginning of the next lesson. The boys have also to keep notes of the lectures and of the laboratory work. The standard aimed at is the power to discover a simple acid and base, and an acquaintance with the text-book. During the summer the chemistry boys have a botany lesson once a fortnight, in order that they may keep up what they had previously learned. In addition to this regular work, Classes I. and II. have occasional lectures either on chemical physics, "Erdkunde," or some such subject. As regards marks, all the various school subjects stand on an equal footing.

The science lessons are very popular with the boys, as is shown by their frequently referring to them out of school, and by their occasionally bringing home plants in order to make them out. But we hope that the boys will retain some considerable amount of knowledge beyond the mere power of making out the flowers given to them, or that of doing simple analysis, and though perhaps few of the younger boys would be able to pass a thoroughly satisfactory *written* examination, in either chemistry or botany, yet a good deal more knowledge might be questioned out of even them by an experienced examiner than they would be able to put upon paper. Mere knowledge of the facts of either science is not the object at which we have been chiefly aiming. These sciences were chosen less as subjects of study than as instruments of training in order to cultivate the powers of observation, and to encourage a habit of inductive reasoning. If the teaching of science in its early stages is thus regarded more as a means than as an end, there is no child, who has begun to learn anything at all, who may not be taught some branch of it with advantage.

At the same time, there is a danger to be avoided.

When we first began teaching botany and chemistry here, I was so strongly impressed by the truth of this view of the proper place of science in education, that I started by making the boys examine flowers and do simple reactions without making them learn anything by heart, hoping to induce them to collect their facts and build up their science for themselves. The result was that they did not know what to do with the facts which they collected, and kept losing them as fast as they picked them up. But since the botany boys have been set to learn the chart by heart, and since the chemistry boys have been using a text-book, the progress made has been far more satisfactory. A young child's reasoning powers are so feeble that he needs to be constantly guided in the use of them, and before being set to observe he requires to be furnished with a "cadre" in which to arrange his battalions of facts.

It may be asked why botany and chemistry should be chosen in preference to other sciences, such as geology or physics, which might seem likely to prove more attractive to boys. Botany was chosen because it is purely a science of perception, of observation and co-ordination of existing facts, and because it calls into play and directs into a useful channel that natural propensity of boys to collect and classify which is seen in butterfly catching and stamp albums. A good deal more might be made of entomology than has hitherto been attempted, but it is rather a holiday than a school subject, the bases of its classification are too minute and even arbitrary, and it has the disadvantage of leading almost of necessity up to subjects too wide for boys to grasp. Chemistry was chosen because it is a science of reflection, and forms the best introduction to the experimental method. In chemical analysis a boy has first to produce the results on which he must afterwards exercise his reason; he has to reflect on and draw his conclusions from not only what he sees, but what he does. He thus learns never to do anything without knowing why he does it and what result he expects to obtain. Chemistry also has the advantage of giving a first insight into the practical applications of mathematics. That indeed is the part of the subject which the majority of boys find most difficult. It is rare to find a boy who will readily work out arithmetically even a simple reaction. In the only possible rival to chemistry—physics—the simpler phenomena are much less varied and interesting, the bond of union between them is less apparent, the reasoning from effect to cause less patent, and there are comparatively few experiments which a child could perform for itself. Physics form an admirable lecture subject, but even then the necessary mathematical reasoning is far beyond the capacity of an average boy of twelve. Such subjects as geology and astronomy may be made most interesting, and a great deal may be done by directing children's attention to the physical actions going on in the world around them, but they are what, from a schoolmaster's point of view, I should call informational rather than educational sciences, their phenomena are generally too vast for a child's mind really to exercise itself upon them.

It will have been noticed that in no case are we able to give to science the full six hours per week recommended by the Commissioners. I would gladly do so, but do not think that it would be possible unless the standard for the classical entrance scholarships at the public schools, which of necessity fixes that of the first class at private schools, were lower than it is now, and although the entrance scholarships have raised this standard considerably above what it was only a few years ago, yet I do not think that it would be desirable to lower it, at least in translation and grammar. In composition, and especially in verse composition, I think it is a matter for consideration whether classical scholarship really benefits by expecting so much from very young boys; whether they would not learn to appreciate the delicacies of style more quickly and thoroughly if they did not spend so much time over artificial composition before they have gained that natural facility of expressing their thoughts in their own tongue which only practice and varied reading can give; and whether therefore some part of the time now given to that subject might not, in many cases at least, be more usefully employed on other subjects, such as science and English composition, or perhaps drawing, in which boys naturally take a keen interest, and which certainly tend to give breadth of view and largeness of mind, and what is equally important, "a ready wit." Even in translation boys fail much oftener from want of knowledge of English than from want of power to construe. At present the number of entrance scholarships in which science counts for anything is so small that they may be disregarded, and certainly nothing could be less desirable for the interests of science itself, or more productive of "cram," than for scholarships to be given to boys in science alone. Would it not, however, be possible for the classical composition standard to be lowered in a considerable number of scholarships, and for one-third or one-half of the marks in them to be given to science, including practical work? The remaining scholarships might keep to their present standard in every respect, a standard which is certainly not at all too high for boys who possess real literary power, and possibly not for average boys who do not seem to possess any special bias either towards the literary or the scientific side. A plan of this sort would avoid giving that encouragement to "modern sides" which would be given by special science scholarships, and that would be an advantage, for any bifurcating arrangement is always practically very difficult to work, and has never yet produced a satisfactory result either in science or in classics.

The Commissioners are, I believe, in the right in thinking that education should be brought under the great law of progress from the more general to the special, and that it will be quite soon enough for any ordinary student to begin to concentrate all his energies on that particular line of study which is likely to prove the most valuable to him in his future career, when he has entered the university, and ought therefore to be of such an age and discretion as to be able to decide for himself what will be the probable course of his future life. From this opinion it is true that Prof. Stokes dissents, on the ground that "a wider discretion should be left to the governing bodies or head masters as to the degree to which what has been called 'stratification' of studies should be carried out." Now I am convinced, not only from theory, but from practical experience, that though stratification is undoubtedly the right course for an adult to pursue, yet that the advocates of that system do not make sufficient allowance for the intense love of novelty innate in a child, nor for the incapacity of a brain not fully developed of sustained application to any one subject. We have been led here, little by little, to diminish the length of the lessons in every subject until now scarcely any lesson exceeds half, or at the most three-quarters, of an hour in length; and the masters all agree in saying that with fairly intelligent boys they can get quite as much work done in the shorter time as in the longer. No boy can fix his attention on one subject for long together, and the moment it flags he might just as well be out in the playground as in the school-room. But if, before he has got weary of one subject, another which interests him is brought before him, he will turn to it with as much zest as if he were just beginning work. It has more than once happened that a boy in this school has needed to give special attention to certain subjects. Formerly I used to take such a boy out of his less important classes, in order that he might give extra time to his special subject. But in no case have we found that such a boy at the end of the term has made any sensible progress beyond his fellows who had continued doing their ordinary more varied work. Though some part of this might be owing to his being outside the regular classes, yet by far the greater part was due to the monotonous work palling upon him and dulling his brain.

The education of young children should be made like their picture-books. The pictures should be such as will induce the little learner to read and study the letterpress in order to find out more about them, and for that purpose they can scarcely be too numerous. A boy when his mind first opens to the world around him is like a man in a large strange house. He must needs go about and learn the arrangement of the building, peer into every room, examine the varied prospect from every window, before he can decide which rooms he will make his own; but when once he has made his choice, he will probably keep to one or two rooms and seldom enter the others.*

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THE THEORY OF "STREAM LINES" IN RELATION TO THE RESISTANCE OF SHIPS†

THE address of the President of a Section would year by year possess an appropriate interest, if it could always consist of an exposition of the progress made during the past year in the department of science which the Section embraces. And many of the addresses to this and other sections have conformed to this pattern with marked success.

But the adequate preparation of an address shaped in this approved mould would require a range of experience and a grasp of thought such as few possess; and custom has wisely sanctioned a type of address which, though less appropriate to the occasion, need not be either uninteresting or inapposite. And we, in this Section, have not to search far for instances in which its President has charmed and instructed us by a masterful exposition of some single subject in practical science, or by a timely reminder of the improvident manner in which we deal with some precious store of natural wealth.

I must express a hope that it will not be regarded as a conversion of liberty into license, if the subject I have chosen obliges me to introduce a further innovation, and to use diagrams and experiments in order to make my meaning clear.

I propose to treat of certain of the fundamental principles which govern the behaviour of fluid, and this with special reference to the resistance of ships. By the term "resistance" I mean the opposing force which a ship experiences in its progress through the water.

Considering the immense aggregate amount of power expended in the propulsion of ships, or, in other words, in overcoming the resistance of ships, I trust you will look favourably on an attempt to elucidate the causes of this resistance. It is true that improved results in ship-building have been obtained through accumulated experience; but it unfortunately happens that many of the theories by which this experience is commonly interpreted, are interwoven with fundamental fallacies, which, passing for principles, lead to mischievous results when again applied beyond the limits of actual experience.

The resistance experienced by ships is but a branch of the general question of the forces which act on a body moving through a fluid, and has within a comparatively recent period been placed in an entirely new light by what is commonly called the theory of stream-lines.

The theory as a whole involves mathematics of the highest order, reaching alike beyond my ken and my purpose; but I believe that, so far as it concerns the resistance of ships, it can be sufficiently understood without the help of technical mathematics; and I will endeavour to explain the course which I have myself found most conducive to its easy apprehension.

It is convenient to consider first the case of a completely submerged body moving in a straight line with uniform speed through an unlimited ocean of fluid. A fish in deep water, a submarine motive torpedo, a sounding lead while descending through the water, if moving at uniform speed, are all examples of the case I am dealing with.

It is a common but erroneous belief that a body thus moving experiences resistance to its onward motion by an increase of pressure on its head end, and a diminution of pressure on its tail end. It is thus supposed that the entire head end of the body has to keep on exerting pressure to drive the fluid out of the way, to force a passage for the body, and that the entire tail end has to keep on exerting a kind of suction on the fluid to induce it to close in again—that there is, in fact, what is termed *plus* pressure throughout the head end of the body, and *minus* pressure or partial vacuum throughout the tail end.

This is not so; the resistance to the progress of the body is not due to these causes. The theory of stream-lines discloses to us the startling but true proposition, that a submerged body, if moving at a uniform speed through a perfect fluid, would encounter no resistance whatever. By a perfect fluid, I mean a fluid which is free from viscosity, or quasi-solidity, and in which no friction is caused by the sliding of the particles of the fluid past one another, or past the surface of the body.

The property which I describe as "quasi-solidity" must not be confused with that which persons have in their minds when they use the term "solid water." When people in this sense speak of water as being "solid," they refer to the *sensation* of solidity experienced on striking the water-surface with the hand, or to the reaction encountered by an oar-blade or propeller. What I mean by "quasi-solidity," is the sort of stiffness which is conspicuous in tar or liquid mud; and this property undoubtedly exists in water, though in a very small degree. But the sensation of solid reaction which is encountered by the hand or the oar-blade, is not in any way due to this property, but to the *inertia* of the water: it is in effect this inertia which is erroneously termed solidity; and this inertia is possessed by the perfect fluid, with which we are going to deal, as fully as by water. Nevertheless it is true, as I am presently going to show you, that the perfect fluid would offer no resistance to a submerged body moving through it at a steady speed. It will be seen that the apparent contradiction in terms which I have just advanced is cleared up by the circumstance, that in the one case we are dealing with steady motion, and in the other case with the initiation or growth of motion.

In the case of a completely submerged body in the midst of an ocean of perfect fluid, unlimited in every direction, I need hardly argue that it is immaterial whether we consider the body as moving uniformly through the ocean of fluid, or the ocean of fluid as moving uniformly past the body.

The proposition that the motion of a body through a perfect fluid is unresisted, or, what is the same thing, that the motion of a perfect fluid past a body has no tendency to push it in the direction in which the fluid is flowing, is a novel one to many persons; and to such it must seem extremely startling. It arises from a general principle of fluid motion, which I shall presently put before you in detail—namely, that to cause a perfect fluid to change its condition of flow in any manner whatever, and ultimately to return to its original condition of flow, does not require, nay, does not admit of, the expenditure of any power, whether the fluid be caused to flow in a curved path, as it must do in order to get round a stationary body which stands in its way, or to flow with altered speed, as it must do in order to get through the local contraction of channel which the presence of the stationary body practically creates. Power, it may indeed be said, is first expended, and force exerted to communicate certain motions to the fluid; but that same power will ultimately be given back, and the force counterbalanced, when the fluid yields up the motion which has been communicated to it, and returns to its original condition.

I shall commence by illustrating the action on a small scale by fluid flowing through variously shaped pipes; and I must premise that in the greater part of what I shall have to say, I shall not require to take account of absolute hydrostatic pressures. The flow of water through pipes is uninfluenced by the absolute pressure of the water.

I will begin with a very simple case, which I will treat in some detail, and which will serve to show the nature of the argument I am about to submit to you.

Suppose a rigid pipe of uniform sectional area, of the form shown in Fig. 1, something like the form of the water-line of a vessel.

The portions AB, BC, CD, DE are supposed to be equal in length, and of the same curvature, the pipe terminating at E in exactly the same straight line in which it commenced at A, so

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* My experience has been entirely with boys, but I feel sure that elementary science might be taught with at least equal advantage to little girls.

† Address to the Mechanical Section of the British Association, Bristol, August 25, 1875; by William Froude, C.E., M.A., F.R.S. President of the Section. Revised and extended by the author.